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CONTENTS

The Interpretation of Nature: PROFESSOR WM. T. SEDGWICK 169

The Fitness of Organisms from an Embryologist's Viewpoint: PROFESSOR B. F. KINGSBURY 174

The Final Examination of Seniors in American Colleges: PROFESSOR GREGORY D. WALCOTT 179

William McMurtrie: PROFESSOR EDWARD HART 185

Publications of the Department of Agriculture 187

Scientific Notes and News 188

University and Educational News 192

Discussion and Correspondence:—
Three Ice Storms: CHARLES F. BROOKS. *A Phlebotomus the Practically Certain Carrier of Verruga:* DR. CHARLES H. T. TOWNSEND 193

Scientific Books:—
Thresh on the Examination of Waters and Water Supplies: PROFESSOR GEORGE C. WHIPPLE. *Arber's Herbals, their Origin and Evolution:* PROFESSOR CHARLES E. BESSEY. *Jordan's Vergleichende Physiologie Wirbelloser Tiere:* DR. OTTO GLASER. *Göldi on Die sanitarisch-pathologische Bedeutung der Insekten und verwandten Fliedertiere:* DR. CHARLES T. BRUES..... 195

Scientific Journals and Articles 200

Branch Movements Induced by Changes of Temperature: J. G. GROSSENBACHER 201

Special Articles:—
"Yellow" and "Agouti" Factors in Mice: C. C. LITTLE. *Antigravitational Gradation:* DR. CHARLES R. KEYES 205

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THE INTERPRETATION OF NATURE AND THE TEACHING LABORATORY[1]

There is a universal tendency among mankind to conceive all beings like themselves and to transfer to every object those qualities with which they are familiarly acquainted.—David Hume, 1817.

I

IN all ages human conduct has been largely determined by contemporary opinion, and contemporary opinion by current interpretations of nature. When, for example, the Greeks held that the sun was a god, driving a chariot of fire daily across the sky, it was natural for them to worship and revere the sun as the great giver of light and life. For us moderns, holding, as we do, that the sun is a flaming globe of gas, to do likewise is impossible. Savages, believing that disease is due to demoniacal possession, naturally employ charms for prevention and incantations for cure, while we, holding as we do, that typhoid fever comes only by microbes discharged by antecedent cases of that disease, invoke for prevention disinfection of excreta and protective inoculation, and for cure reinforcement of the vital resistance of the patient. In all cases conduct is determined, consciously or unconsciously, by contemporary interpretations of nature, and we shall find it instructive as well as helpful to review briefly some of those accepted interpretations of the past which for longer or shorter times have occupied the minds of men.

And first we must touch upon those savage and barbarous interpretations character-

[1] An address at Bates College on the dedication of the Carnegie Laboratories of Physics and Biology, January 14, 1913.

istic of the childhood of the race in which everything outside of man is interpreted as essentially manlike in essence, life more or less manlike being assumed to be everywhere—in sea and sky and air and earth—acting in manlike ways and thinking manlike thoughts. This interpretation, the basis of much of our most imaginative speech and poetry, is still fascinating and full of interest.

We need not here raise the world-old questions of realism versus idealism in philosophy. In the childhood of the race, as in the childhood of every one of us today, the visible universe was intensely personal, palpitating with a life closely similar to our own and only gradually separated from it by the slow teachings of experience. For precisely as the child of to-day gazes upon kitten, doll or dog and interprets these as charged with a life and character similar to his own, so in the childhood of the race mankind saw in the wind-swept tree, generally at rest but sometimes swayed as by an unseen hand, a living agency to whose touch the awakened tree responds as if from sleeping or dreaming, now by deep sighs or soft murmurs, now by groaning or roaring. And when Lowell in his "Under the Willows" exclaims, "My Elmwood chimneys seem crooning to me," he is simply making modern poetical use of a fireside music which by his remote ancestors would have been interpreted as spirit voices.

It was doubtless one of the greatest forward steps ever made in the emancipation of the human intellect when Pythagoras of Samos before the Golden Age of Greece detected a constant and impersonal relation between the length of a vibrating string and the sound which accompanied it. This discovery of the monochord still stands as the very foundation of acoustics in spite of the fact that it was immediately misinterpreted by Pythagoras and his followers as signifying a universal relation between sound and music and number, and a universal existence of undetected harmony in seemingly silent bodies, an interpretation which lingers even yet in the phrase "the music of the spheres," and has furnished us with many beautiful lines of poetry, such as those of Shakespeare and Milton, and the following much later, from Pope's "Essay on Man":

> If Nature thundered in his opening ears
> And stunned him with the music of the spheres,
> How would he wish that heaven had left him still
> The whispering zephyr and the purling rill.

Longfellow only yesterday referred to

> The Samian's great Æolian lyre
> Rising through all its seven-fold bars
> From earth unto the fixed stars
> And through the dewy atmosphere
> Not only could I see but hear
> Its wondrous and harmonious strings
> In sweet vibration sphere by sphere.
> —"The Occultation of Orion."

And

> even in recent times no meaner a philosopher than Karl Ernst von Baer has asked if there is not "perhaps a murmur in universal space, a harmony of the spheres, audible to quite other ears than ours." (Gomperz.)

Yet Pythagoras lived not long before the golden age of Greece and we do not find even among the Greek nature philosophers many less mystical interpretations.

Students of the history of mathematics refer to three famous mathematical problems of antiquity as "the three classical problems," so called because no satisfactory solution of them could be found; but external nature and inductive science had also their "classical" problems, such as the meaning of day and night, the periodic coming and going of the seasons, the rhythmic phases of the moon, the annual rise of the Nile, the winds, the pulsating tides, all sorts of sounds and music, the origin of man and of the lower animals

and plants, the significance of life, death, generation, sleep and dreams. These were all perennial problems and all insoluble. The men of Greece moved as in a maze, not only ignorant, as we are, of man's origin and fate, but, unlike us, dreading the things around them, since most of these, like the lightning and the hurricane, were not only not interpreted but seemingly might come at any moment to kill or to crush.

> At first man stands before the roaring loom of Time, gazing in helpless perplexity at the movements of the infinite shuttles, ignorant of the movements which may be beneficent and of those which may be destructive to him. . . . He has to find his friends and his foes amid the multitude of forces which surround him. . . . The spontaneous activity of his growing intellect urges him to make out some scheme by which the various phenomena may be bound together. He begins to link the known and accessible on to the unknown and inaccessible; he animates the universe; interprets all he sees by all he feels.—G. H. Lewes.

This childlike anthropomorphism, however, failed to satisfy the minds of the more cultivated Greeks, who, having nothing else to fall back upon, retreated from it into a kind of agnosticism or into crude forms of atomism such as that of Democritus. Even the great Hippocrates, while pleading for observation and virtually beginning clinical observation as well as holding to the healing power of nature, was so ignorant of anatomy and physiology and pathology as to be able to offer nothing better as a theory of disease than his well-known suggestion of the four humors, of which the sole merit—though at that time a very great merit—was that it focused attention upon the patient rather than on priest or temple or bloody sacrifice; that is to say, on the disease itself rather than on some ancient dogma. Empedocles, it is true, is believed to have used natural means to forestall disease when he cut down the hill behind Girgenti and drained the malarial marshes of Selenunti, the parsley city. Aristotle, too, for the most part seems far away from anthropomorphism in most of his thought and work, but while all the middle age regarded him with Dante as "the master of those who know," Lewes has truly said:

> It is difficult to speak of Aristotle without exaggeration; he is felt to be so mighty and is known to be so wrong. . . . His influence has only been exceeded by the great founders of religions; nevertheless, if we now estimate the product of his labors in the discovery of positive truths, it appears insignificant when not erroneous. None of the great germinal discoveries in science was due to him or his disciples.

The Roman period was practically sterile as to any helpful interpretations of nature, the great work of Lucretius being for the most part an amplification of that of Epicurus; while the triumph of christianity and, later, of Mohammedanism over the Roman world, or parts of it, merely imposed upon it oriental interpretations which by substituting few gods or one for the multitudes of Greek mythology, simplified without wholly depersonifying nature. It may well be, however, that the introduction of the Hebrew Scriptures into the western world afforded a real relief from the overhumanized and top-heavy interpretation of the Greeks and Romans. What a cool refreshment follows, for example, a verse like this taken from those Scriptures: "The wind bloweth where it listeth; thou hearest the sound thereof, but canst not tell whence it cometh or whither it goeth." Here is no excessive anthropomorphism. The wind and its blowing do not strike us as interpreted differently from our explanations of to-day. Sound is personified, but at the same time we have a frank admission of ignorance as to its origin and fate. As opposed to the theory of Æolian origin and the assumption of personality we have

cool, calm abstraction which may well have been grateful even to Greeks weary of a refined anthropomorphism.

All through the dark and the middle ages interpretations of nature more or less anthropomorphic and childlike remained common. Shakespeare is deeply tinged with them, while Francis Bacon, catching cold and dying from his famous experiment on the cold storage of poultry, stands out as even more original for this than as the author of the "Novum Organum." It is the glory of the Renaissance that it began the age of experiment. Hippocrates had displayed something of the modern spirit, but he was born too soon. Roger Bacon had it in fuller measure and paved the way for Gutenberg and Copernicus and Leonardo da Vinci and Columbus and Gilbert and Magellan. In the sixteenth and seventeenth centuries for the first time in history a succession of ardent students investigated, and in our modern fashion interpreted, the external world.

Thenceforward events moved rapidly. Galileo and Kepler were followed by Harvey and Boyle and Newton; the telescope, the thermometer, the barometer and the compound microscope came into being; scientific societies sprang up and the modern order began. Old interpretations gradually passed away. All things gradually became new. Matter and energy in myriad forms and combinations replaced the gods of old, with the result that since the time of Newton man has looked out upon the world about him, without fear and as if upon the face of a friend.

II

Teaching must forever recapitulate and epitomize the achievements of the race. Consciously or unconsciously it acts along the lines of the biogenetic law. Beginning with the child who thinks as a child, it offers to him fairy tales in which nature is personified and encourages (note the word) him to see in things about him a life akin to his own. Then comes the awakening, when Santa Claus becomes a benevolent myth and dolls are discovered to be stuffed with sawdust. Next follows the slow recognition of earth and sky, of sun, moon and stars as inanimate objects, and finally the discovery of law and order in the universe.

To facilitate and abbreviate this process and to ensure a sound result, teachers of natural philosophy in the old days performed experiments before their classes. Then came the teaching laboratory, not so much as a workshop as a place for demonstration, experiment and research. The real workshop or laboring place is oftenest none of these, but simply a space in which routine operations of one or various kinds are done over and over again for profit, as, for example, in a shoeshop, a box factory or a cotton mill. The college laboratory of physics and biology is not, and never should be, this sort of workshop. It is rather a place where such demonstrations of principles or processes are made as shall serve for education rather than commerce. A place where old and perhaps famous experiments, chosen for their educational value, can be performed with and by successive classes, and where investigations that promise to yield new or improved results can be prosecuted under favorable conditions. It supplies the room, the apparatus, the power, the raw materials and especially expert and wise guidance, by means of which a personal knowledge of nature can be gained in orderly fashion, and a fundamental and lasting training effectively acquired. It is an indispensable tool or instrument with which to gain rapid and intimate personal acquaintance with nature and the laws of nature. It should

afford for the student a kind of moving picture of the progress and the conquests of science. With the vast extension of the field of knowledge during the last three hundred years it has become impossible for any one to grasp the enormous quantity of facts at our disposal. And yet the child, instead of beginning where his father left off, must begin exactly where his father did. Hence the urgent need of careful choice of facts, choice of experiments, of apparatus and of educational machinery if he is to go in one short life even a little further than his father went. In short, the modern college laboratory is not so much a workshop as a school room, in which selected natural phenomena, facts and processes may be conveniently, rapidly and successively demonstrated and enforced. It should provide at the outset an epitomized, easy and rapid recapitulation of the slow and laborious discoveries of the past, and thus somewhat resemble the museum of art or natural history which likewise affords examples or models of past achievement. That it is essentially dynamical while the museum is statical alters nothing of its recapitulative educational function; that it must necessarily compress the long history of the past into a short time, so that it shall give only an epitome of human progress, is inevitable, and if well done is not merely unobjectionable but desirable.

We hear much nowadays of economy and efficiency in education, as elsewhere, but we have yet to learn that true efficiency in education is not to be measured so much by the number of hours devoted by the teacher to his pupils or to his laboratory or by the time spent by scholars upon their tasks as by the wisdom of his decisions what to teach, and in what order, and especially what to omit. It is easy, though never wise, to seek to cover the whole field, but it is not easy to discover which phenomena, which experiments, which demonstrations are most worth while, most productive of genuine learning, of good judgment, common sense, real wisdom and power.

But whatever our endeavor, this must always be—consciously or unconsciously—an attempt to lead the student on to a sound and true interpretation of nature. And surely the modern interpretation, as we seek and find it in laboratories like this one which we dedicate to-day, is objective rather than subjective. It begins with the rigorous abnegation of ourselves, and a calm survey of the world about us, charged with impersonal matter. The lightning plays about us with the same energy as in Homeric days, but it is no longer Zeus who sends it forth. The waves fling themselves upon our rocky shores to-day precisely as of old they beat upon the islands of the Ægean, but we do not see in them, as did the Greeks, the fury of Poseidon. We see only an almost irresistible pressure of the atmosphere in motion. For us the winds are not the messengers of Æolus, but only lifeless gases caught up and dragged by the swiftly spinning earth or seeking an equilibrium upset by local expansions or contractions due to heat or cold.

Is there, we may well inquire, any more important function for modern scientific education than to interpret, in a laboratory like this which is dedicated to-day, to earnest and eager youths such as the state of Maine sends to her colleges, that nature of which man himself is at once the crowning glory and the principal problem! To inform, to instruct, to adjust—if possible even to attune—the thought, the opinion of youth; to correlate its activities to its environment so that its internal relations may become usefully, efficiently and

happily adjusted to those external relations which were never more complex or more exacting than to-day,—this is our problem. We hear at present much of wars and rumors of wars, and a new social heaven—or at least a new earth that is to become a new heaven. But the universe moves on in its appointed ways. The sun and the moon and the stars and the seasons and day and night are with us, as of old. Plants and animals only slowly change their nature, and mankind is born and lives and dies much as it has always done. Art, to be sure, has become vastly longer, but life is still nearly as short as ever and relatively to the things to be seen, to be learned and to be done, infinitely shorter. The fundamental problem of all education, namely, preparation for life, is therefore no less, but rather infinitely more, important.

But with the aid of laboratories like this, generously furnished by lovers of their kind, in which wise teachers, themselves models of devotion to truth and scholarly living and endeavor, by means of examples, epitomes and recapitulations of the great experiments and discoveries of the past, shall enable their pupils to appropriate forever to themselves and to the service of man the accumulating wisdom of the ages, we may go forward with a cheerful courage. Nor does it seem too much to believe that an interpretation of nature which has robbed it of most of the terrors which it possessed for primitive man and has made it increasingly serviceable to the race, will long endure.

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THE FITNESS OF ORGANISMS FROM AN EMBRYOLOGIST'S VIEWPOINT[1]

I am glad to accept an invitation to address this club, for I believe that it is an excellent custom, indeed, almost necessary in these days of specialization, for a biologist to look at his problems now and then from others' points of view and to be brought into contact with men working on quite different aspects of life than his own. The same fundamental problems face all workers in the biological field, be they ecologists, structure-workers, process-workers, breeders, or, I might add, workers in the broad field of the medical sciences, for I believe that the clinician fully appreciates that the problems of health and disease are, on one aspect at least, problems of life and that medicine on its science side belongs in the broad field of biology. It is the unitary character of life and life phenomena that binds us all together and creates bonds of common interest and the goal toward which we all must strive, whether we know it or not—if the minor problems which we attack are correctly solved—is the explanation of life.

It is a goal which perhaps we may never reach or whose outline at some future time will be made out in but crude and hazy form, and yet it does us good ever and anon to pause in our detailed work of analysis and technique and turn our eyes in the direction we believe it lies and to ponder on the road before; it helps us I believe toward a clearer appreciation of the setting of the petty problems that immediately confront us. Perspective is too apt to be lost in the close scrutiny of high specialization. In such a contemplation from afar of the end-problem of the biologist, some, overwhelmed by what lies between, believe it unattainable; and others proclaim that the solution is close at hand; one sees in the intricacies of life evidences of a vital force while for his fellow-worker the explanation is to be wrought out in terms of physics and chemistry alone. For each the attitude of mind that will color his speculations will be compounded out of his personal make-up, the daily routine of his work and the time and concentration that he has devoted to it. The field naturalist easily inclines toward vitalism; the biochemist, perhaps, is biased toward a physico-chemical interpretation; the structure-worker —and in this group I would place myself—in

[1] Talk before the Agassiz Club of Cornell University, February 24, 1913.